Stationary regime for Standing Wave Central Pattern Generator

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Purpose of research paper

To show that the analysis on surface Electromyographic (sEMG) signals that confirmed the existence of a standing wave Central Pattern Generator (CPG) along the spine is reproducible despite:

1. the evolution of the entrainment technique,
2. different hardware,
3. different data collection protocols.

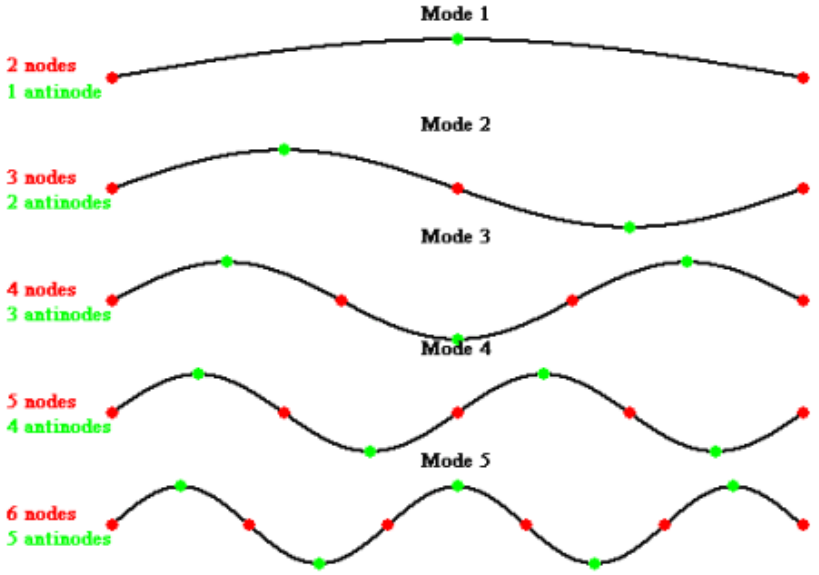
Spinal Wave

It is a phenomenon during which the spine goes through a rhythmic oscillation elicited by light finger pressure at the **neck** and the **sacrum**.

Finger pressure areas

Entrainment procedure

The present study applies to a spinal wave characterized by **two mode** shape standing wave.



Source: Network Spinal Analysis demonstration video. https://www.youtube.com/watch?v=0zRhUmgnIQM

Central Pattern Generator (CPG)

It is an interconnection of neurons that produces a movement of the limbs and/or the trunk that has the following attributes:

1. The movement is rhythmic.
2. It does not require external sensory input once the phenomenon is elicited.
3. The neuronal circuitry is embedded in the spine, without higher cerebral function involvement.
4. It requires some learning or entrainment and it might undergo resetting.
5. It exhibits some wave properties.

Coherence at a distance

It is defined as existence of a standing sEMG wave along the paraspinal muscles.

- Since the spinal standing wave has its coherence extending from the neck to the sacrum, this is a phenomenon of coherence **“at a distance.”**

- Coherence at a distance between sEMG signals is an indication of the central nervous system able to coordinate activities of many muscles.

- Coherence at a distance is present in normal subjects, but depleted in quadriplegic subjects.

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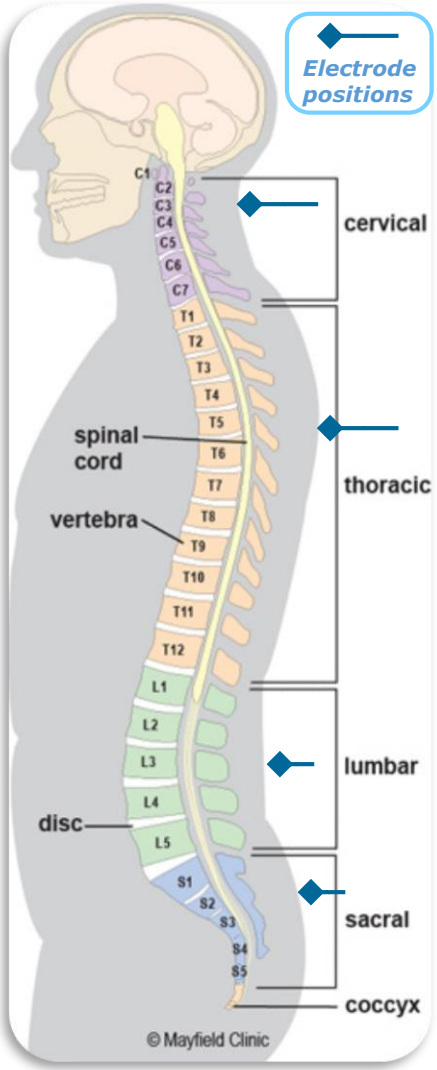
Experimental setup



- The control subject is a **healthy** individual, who signed the IRB-approved informed consent of USC (case UP-06-00152-CR010.)

- **Four** sEMG electrodes were used to record the electrical activity at:
  - cervical (C2-C3),
  - thoracic (T4-T6),
  - lumbar (L3), and
  - sacral (S2-S4) positions.

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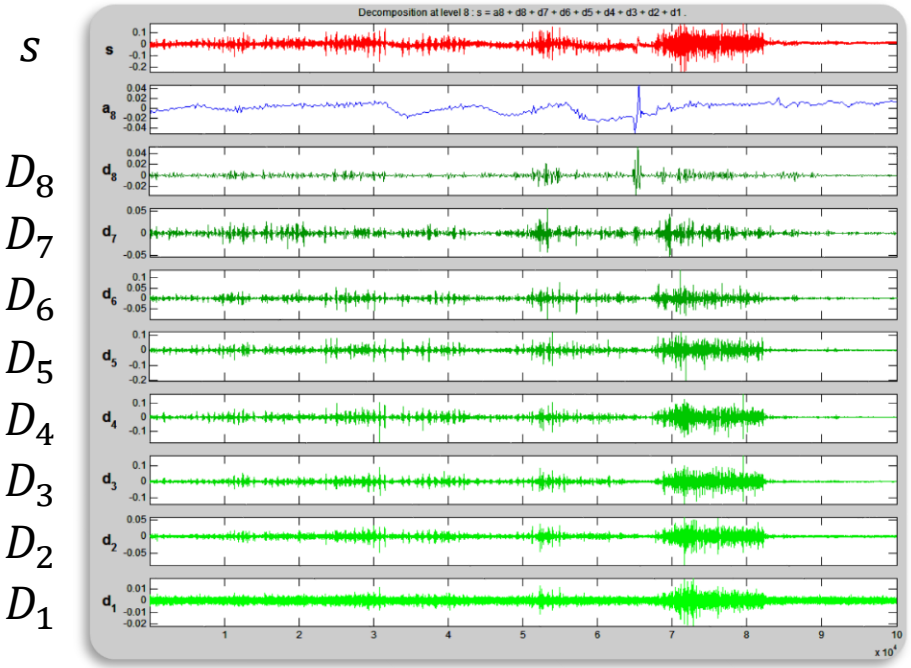
Differences between Old & New protocols

	Old Protocol (2005)	New Protocol (2015)
Sensitive prongs of the electrodes	45° angle relative to spine.	Aligned with the back muscle fibers.
Position of the sacral electrodes	Gluteus	Sacrum
Surface EMG amplifier	Insight Millennium sEMG machine 	INSiGHT Discovery Subluxation Station™ 
Analog-to-Digital conversion	PC-Card DAS16/16 by Computer Boards 	USB-1608FS card (by Measurement Computing) 

Correlation analysis

- The standing wave aspect of the CPG is confirmed by observing the correlation pattern among the cervical, thoracic, lumbar and sacral sEMG signals.
- The correlation pattern appears more clearly on the D_8 and D_7 subbands of the Daubechies DB3 wavelet decomposition.



DB3 Wavelet decomposition from the sacral signal.

Correlation analysis

- Let $y_1(k), y_2(k), y_3(k), y_4(k)$ be either the D_8 subband of the cervical, thoracic, lumbar and sacral sEMG signals respectively. We define the correlations as follows:

$$r_{ij}(s) = \frac{\sum_{k=1}^{K-s} (y_i(k) - \overline{y}_i)(y_j(k+s) - \overline{y}_j)}{\sqrt{\sum_{k=1}^{K-s} (y_i(k) - \overline{y}_i)^2} \sqrt{\sum_{k=1}^{K-s} (y_j(k) - \overline{y}_j)^2}}$$

- The movement has a coherent standing wave if there exist some delays $s_1 < s_2 < \cdots$ such that $r_{ij}(s_l) = 0$, where $i, j = 1,2,3,4$.

- The common points s_l of intersection of all the $r_{ij}(s)$ versus s curves and the $r = 0$ axis have been called **zero correlation nodes** and are manifestations of a coherent standing wave.

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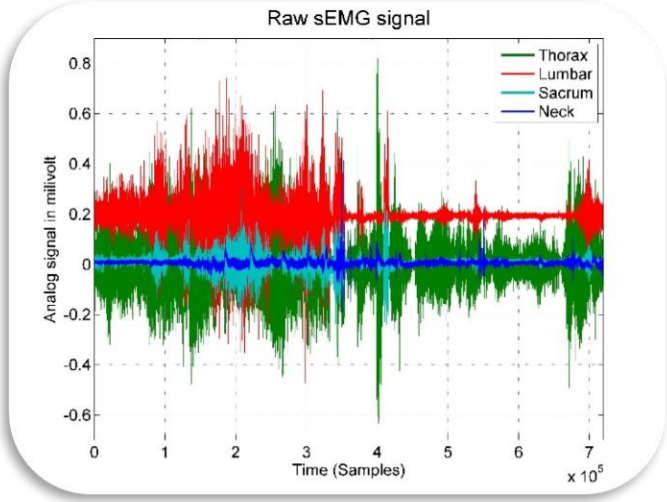
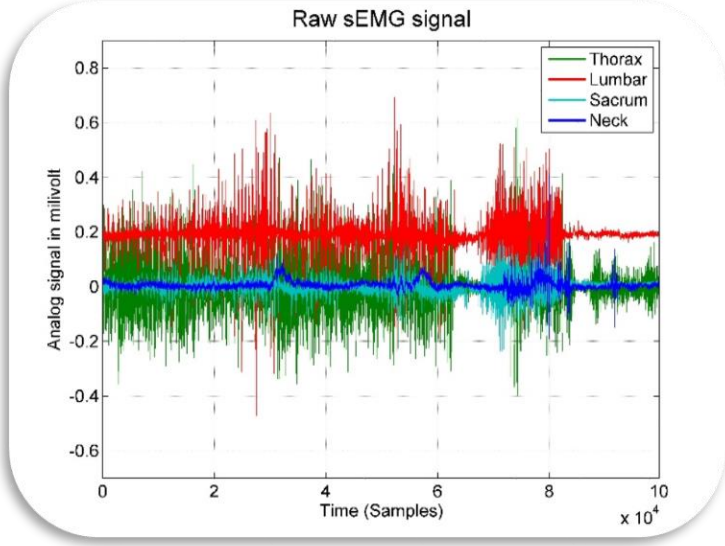
Raw sEMG data

We recorded 720,000 samples at a rate of 4 kHz





We centered the analysis around a section of 100,000 samples, where a synchronicity of signals is visually evident.

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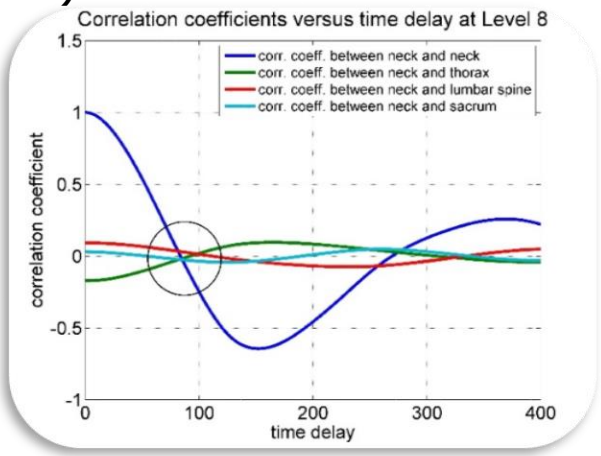
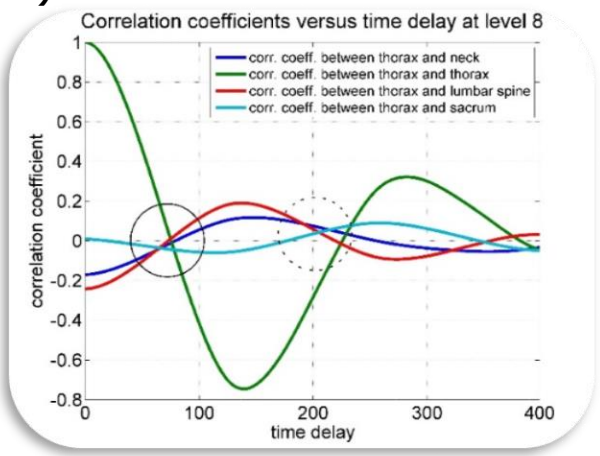
Correlation graphs

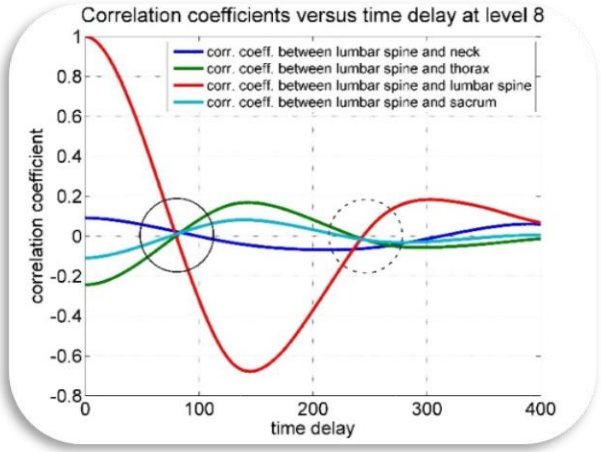
a)



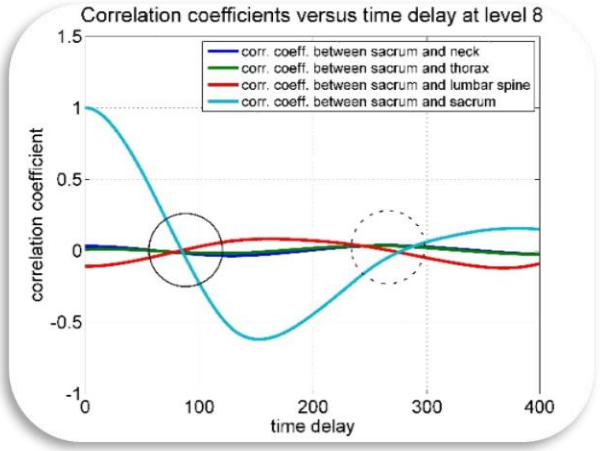
b)



c)



d)



Observe the “zero correlation nodes” at s_1 (black circles,) and s_2 (dotted circles.)

Strong evidence of a coherent standing wave.

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Conclusions & Future work

- We have shown that the results upon which the Central Pattern Generator hypothesis rests are reproducible.

- The spinal wave is a coherent movement elicited by a Central Pattern Generator, opening the road for the potential of this coherence analysis to become part of the neurological suit.

- A statistical test to determine with sufficient confidence when coherence is depleted to a level that should call for a neurological follow up remains to be developed.

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Thank you

Any questions?

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